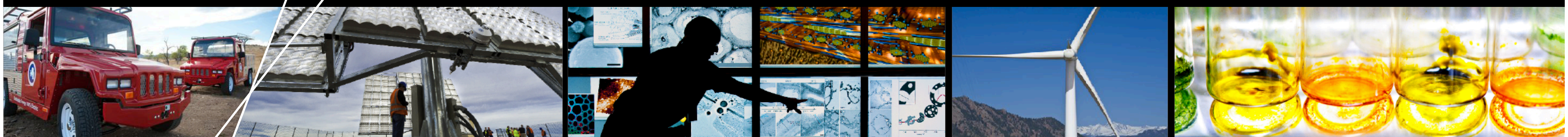
WWSIS Phase 2
Introduction and Input Data

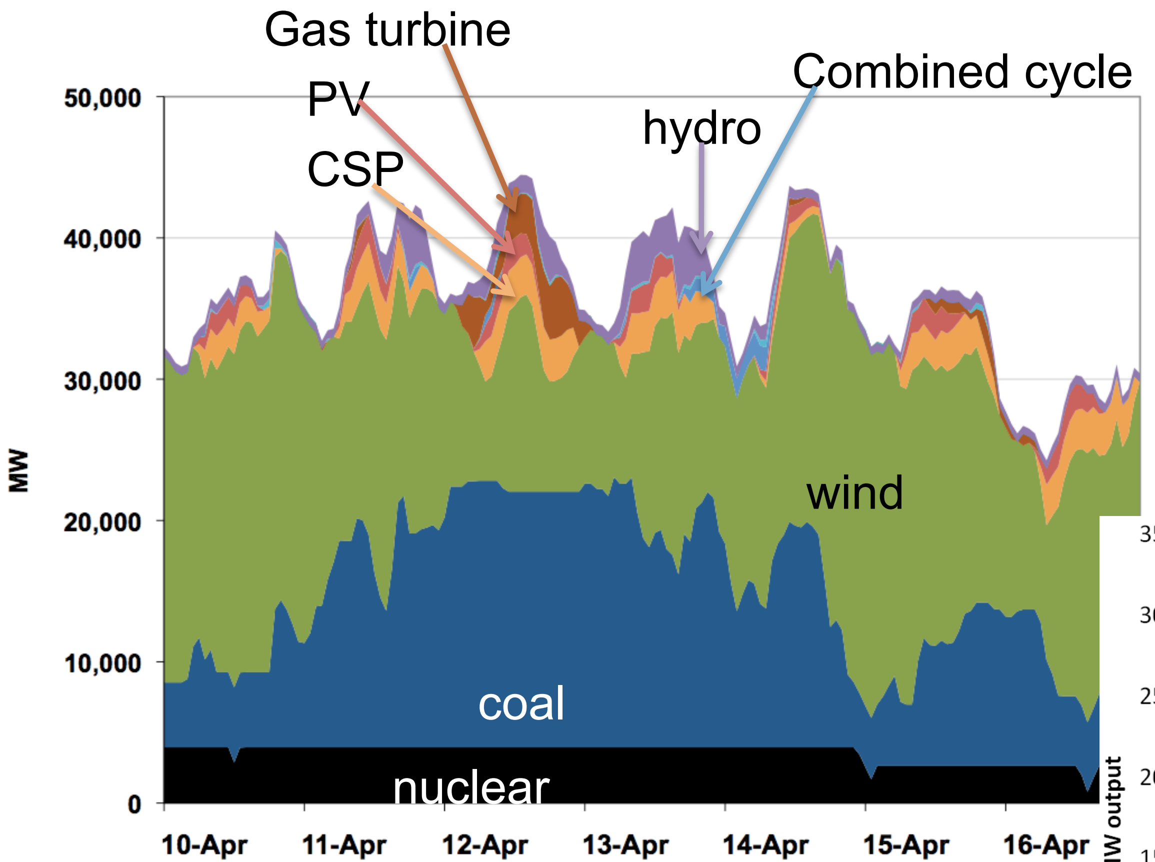


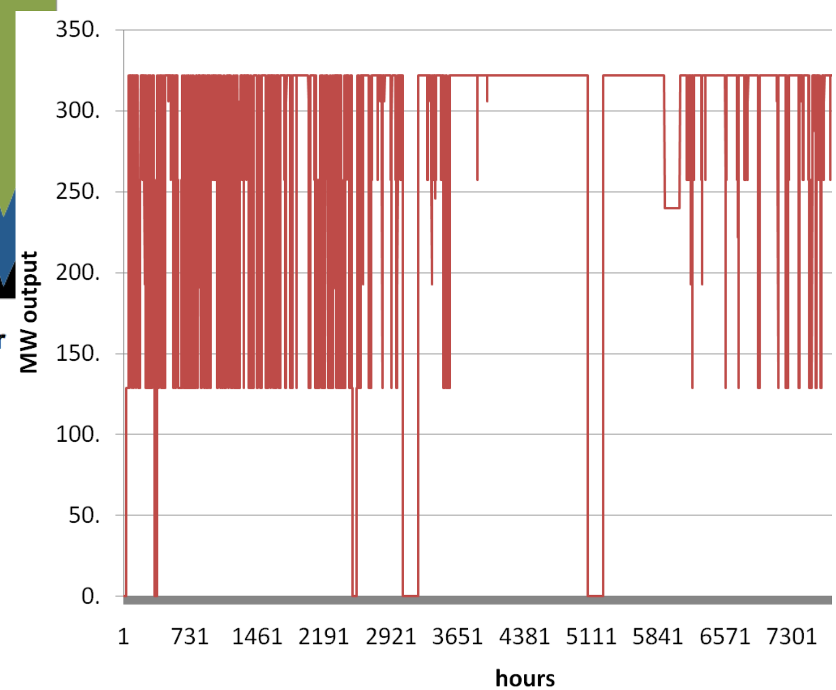
Debbie Lew, NREL

TRC Meeting

Nov 28, 2012

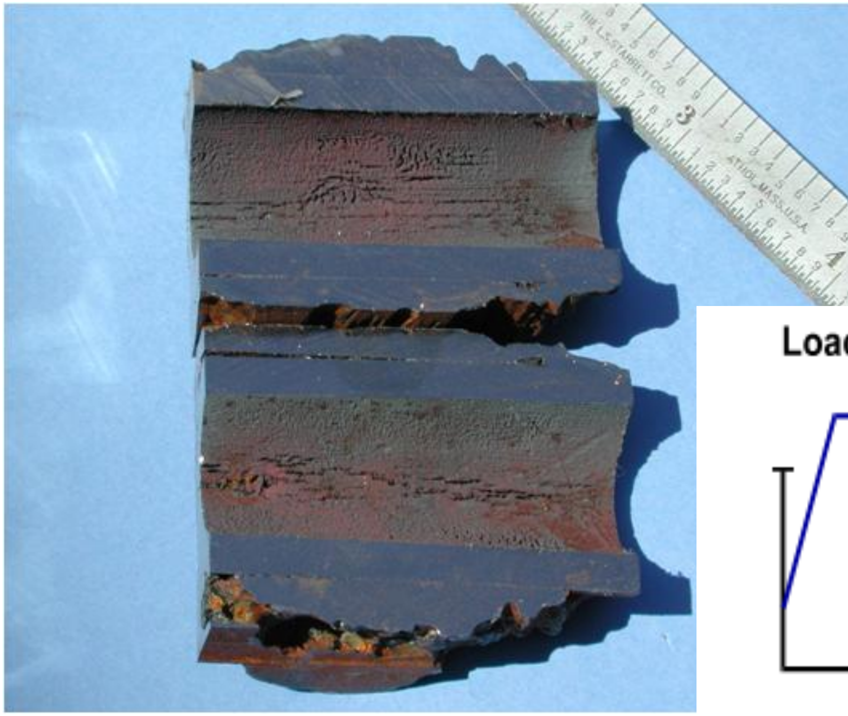
Phase 2 of WWSIS

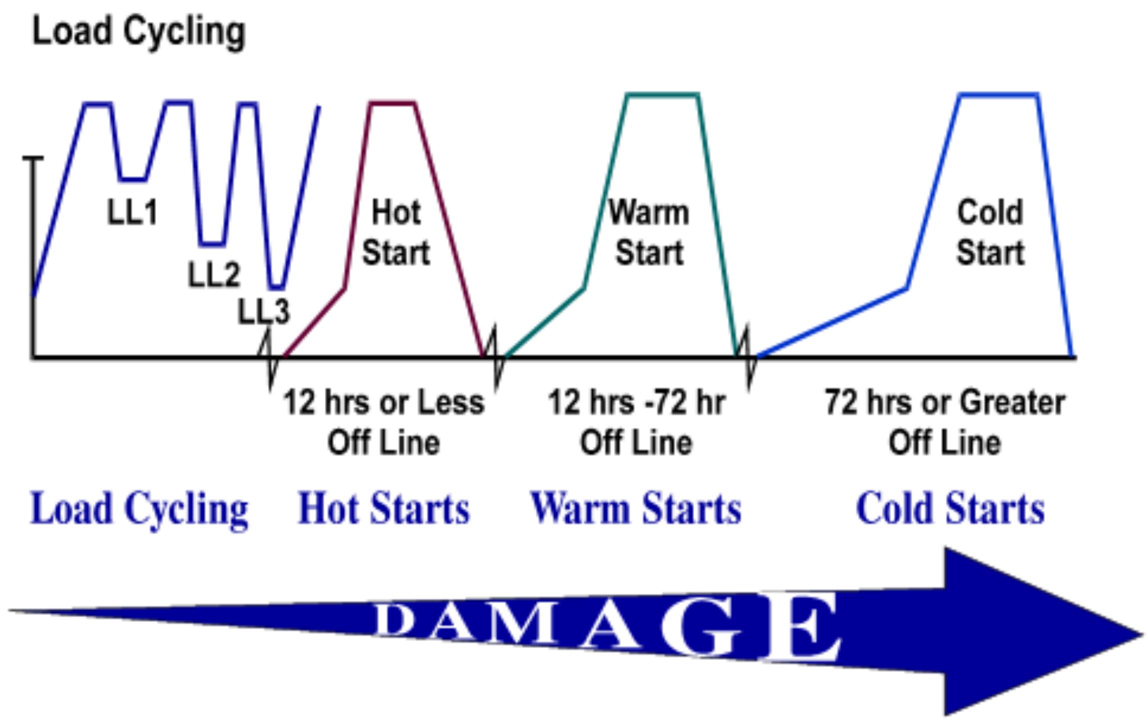




WWSIS1: The worst week of three years

Cycling Leads to Wear-and-Tear





Source: Steve Lefton, Intertek APTECH.

 3

Do wind/solar increase emissions?

Bentek study (April 2010) claims coal cycling results in increases in total SO_2, NO_x and CO_2 emissions in Xcel/PSCO and ERCOT.


Digital Network

Monday, August 23, 2010 As of 12:00 AM New York 57° | 45°

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Wind Power Won't Cool Down the Planet

Often enough it leads to higher carbon emissions.

Article | Comments (243)

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BY ROBERT BRYCE

The wind industry has achieved remarkable growth largely due to the claim that it will provide major reductions in carbon dioxide emissions. There's just one problem: It's not true. A slew of recent studies show that wind-generated electricity likely won't result in any reduction in carbon emissions—or that they'll be so small as to be almost meaningless.

This issue is especially important now that states are mandating that utilities produce arbitrary amounts of their electricity from renewable sources. By 2020, for example, California will require utilities to obtain 33% of their electricity from renewables. About 30 states, including Connecticut, Minnesota ...


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Commentary

A New Study Takes The Wind Out Of Wind Energy

Robert Bryce, 07.19.11, 05:00 PM EDT

Reality has overtaken green hope.

Facts are pesky things. And they're particularly pesky when it comes to the myths about the wind energy business.

For years, it's been an article of faith among advocates of renewables that increased use of wind energy can provide a cost-effective method of reducing carbon dioxide emissions.

Tasks

- Wear and tear costs of cycling and ramping
- Emissions impacts from cycling and ramping
- Optimize unit commitment and 5 minute economic dispatch
- Compare wind and solar

Wear and Tear Costs

Wear and Tear Cost Data

- **Most integration studies do not have specific wear-and-tear costs from ramping/cycling incorporated**
- **Upper Bound and Lower Bound results from analysis of APTECH on 170 plants:**
  - Costs of hot, warm and cold starts
  - Costs of ramping down to minimum output and back up
  - Baseloaded VOM costs
  - Forced outrage rate impacts
  - Long term heat rate degradation
- **7 types of plants:**
  - Coal – small subcritical, large subcritical, super critical
  - Gas – combined cycle, large frame, aeroderivative combustion turbines, steam
  - *Plus 'best in class' units*
- **What we are not considering:**
  - Age, vintage, operating history, design

APTECH Methods to Estimate Cycling Costs

- APTECH has analyzed over 400 units worldwide to estimate impacts of cycling
- 170 units met criteria for inclusion in database to estimate typical costs
  - U.S. units, recently analyzed with newest methods.

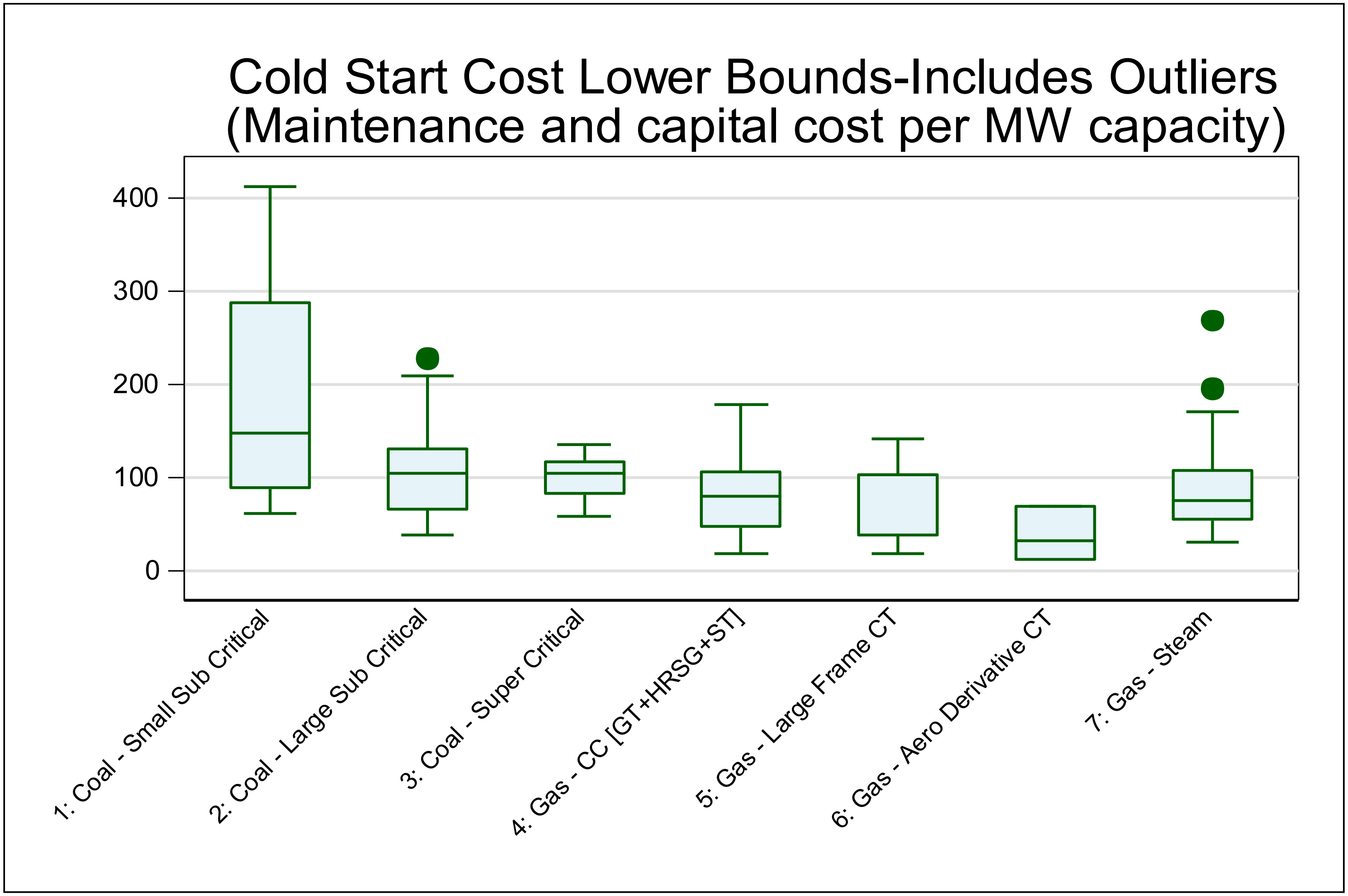
Top-down

- Regression analysis
- Filter all maintenance costs for potential cycling-related repairs
- Include all historical cycling information and maintenance cost timing.

Bottom-up

- Detailed analysis of 7-10 years of work orders
- Specific analysis of all major plant components
- Operator interviews
- Used to confirm top-down analysis.

Wear-and-Tear Costs and Impacts

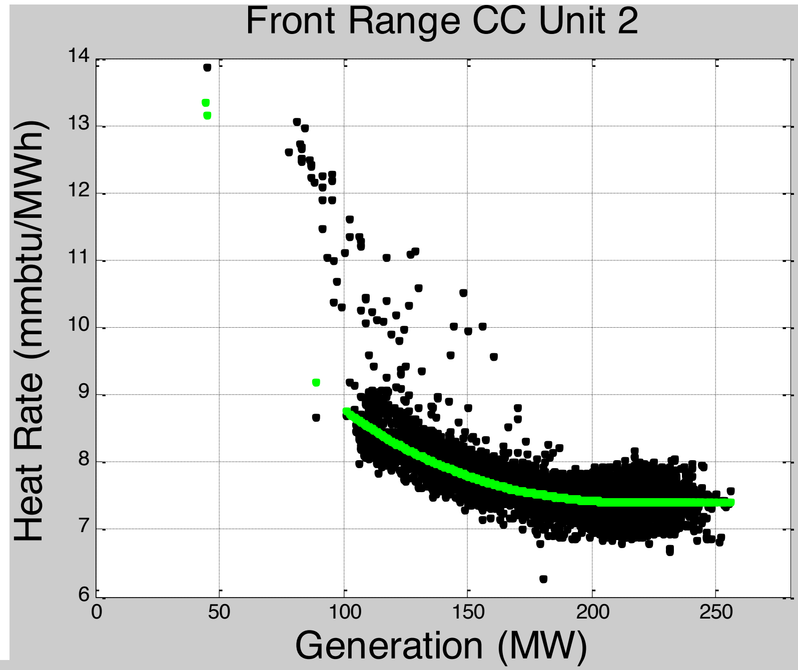


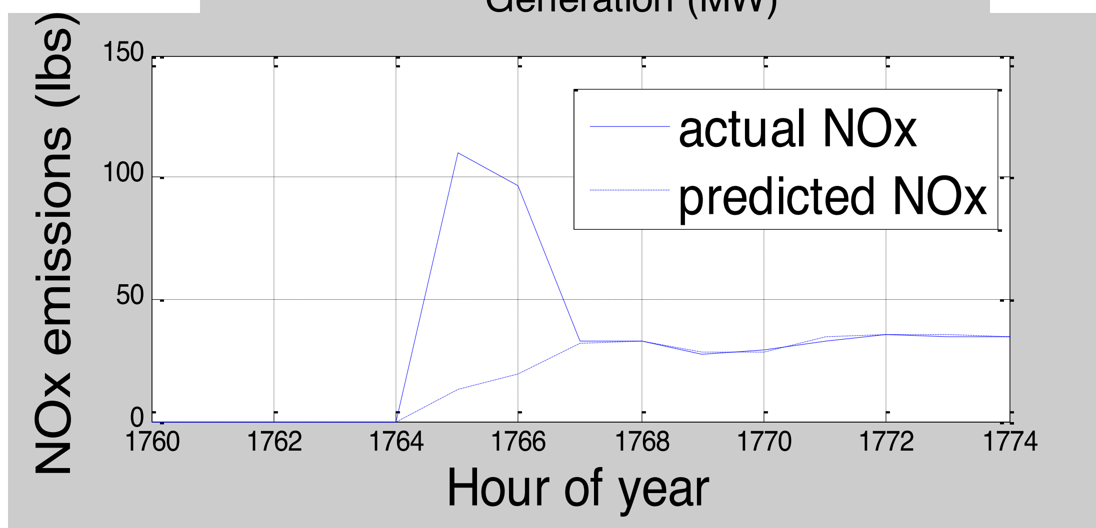
Source: Steve Lefton, www.nrel.gov/docs/fy12osti/55433.pdf

Emissions Impacts

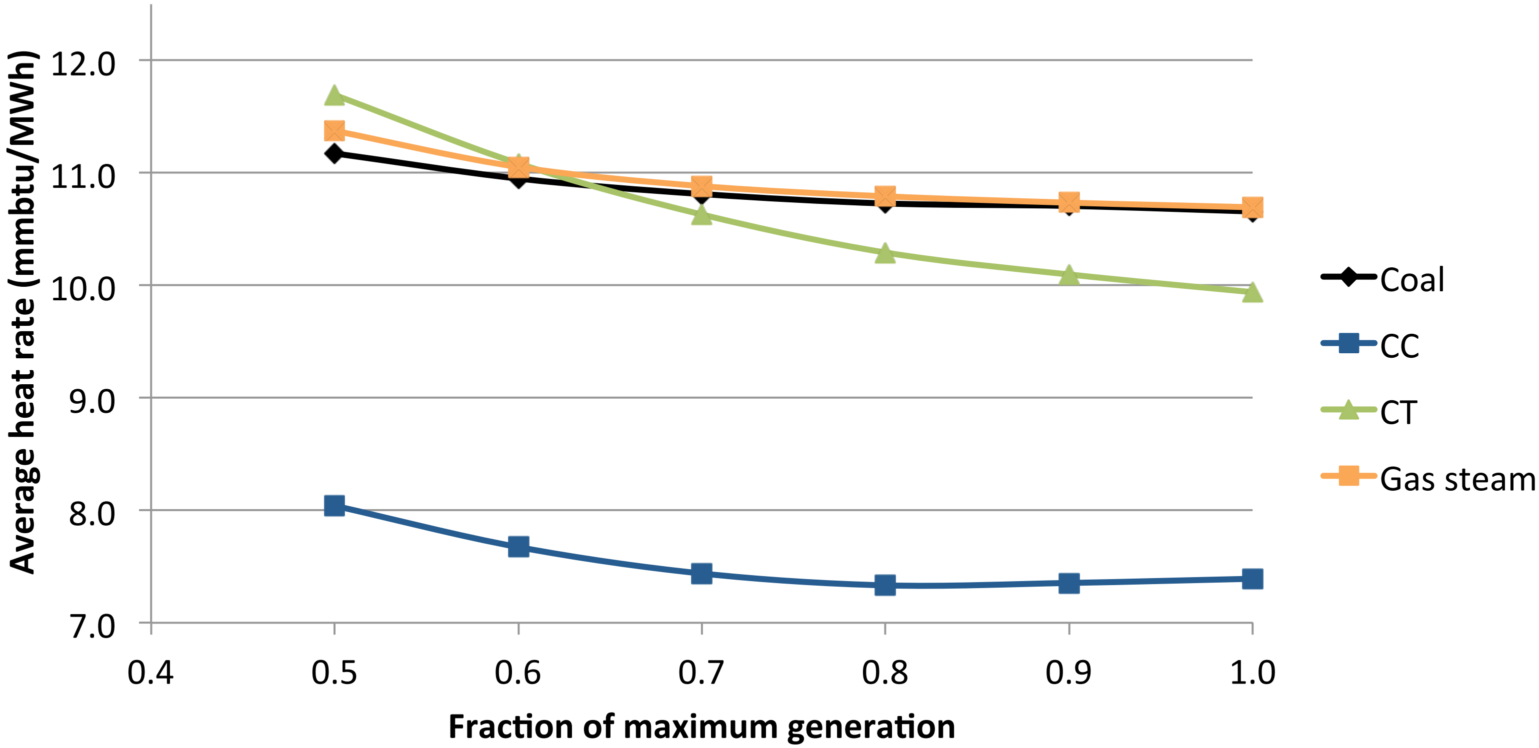
EPA Continuous Emission Monitors

- **Use measured hourly emissions from each fossil fuel plant in the U.S. for 2008**
- **For each plant:**
  - Heat rate (and CO_2 emissions) as a function of generation
  - Emissions (NO_X, SO_2) as a function of generation
  - Emissions due to starts and ramps



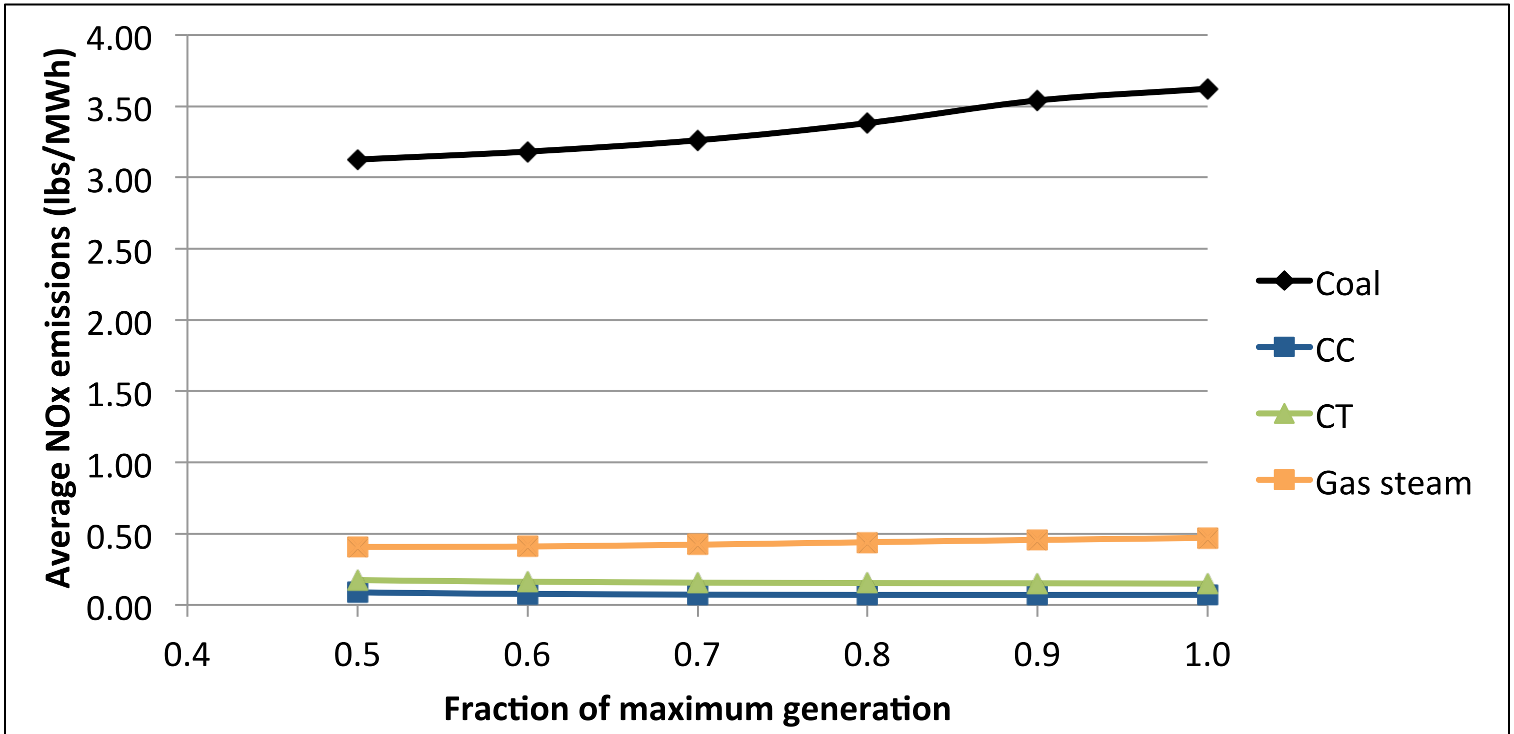


Heat input – WECC averages



mmbtu/MWh	Coal	Gas CC	Gas CT	Gas steam
US – 50% GDC	10.69	9.07	12.31	11.32
US – 100% GDC	10.12	7.87	10.55	10.70
WECC – 50% GDC	11.17	8.04	11.70	11.37
WECC – 100% GDC	10.66	7.39	9.94	10.69

NO_x – WECC averages

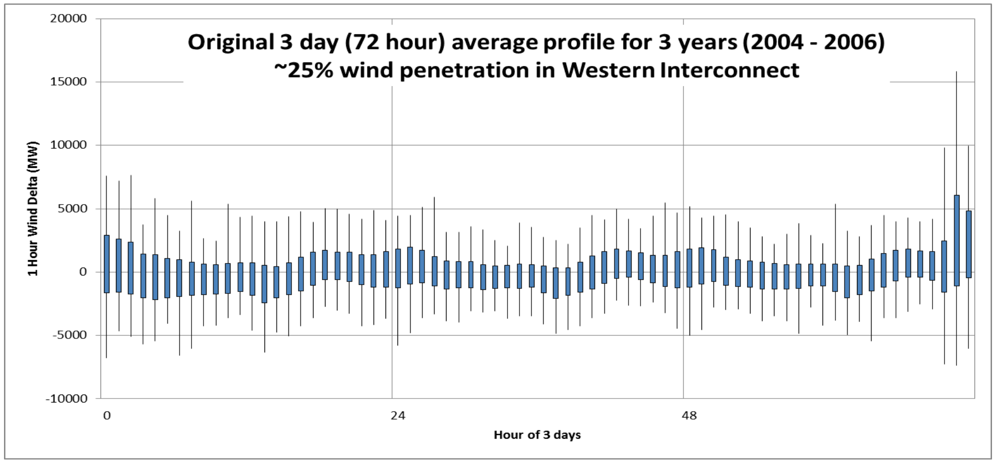


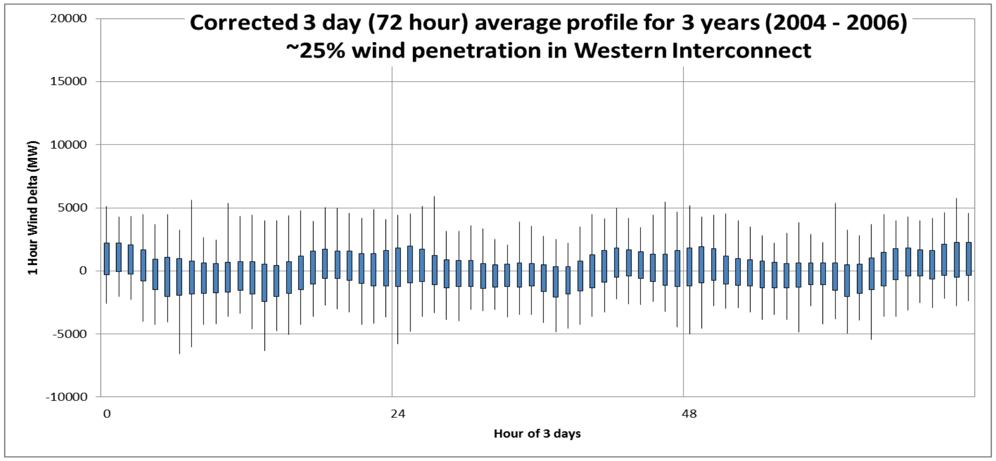
lbs/MWh	Coal	Gas CC	Gas CT	Gas steam
US – 50% GDC	2.66	0.18	0.42	1.86
US – 100% GDC	2.76	0.14	0.36	2.31
WECC – 50% GDC	3.13	0.09	0.17	0.41
WECC – 100% GDC	3.62	0.07	0.15	0.47

Wind Data

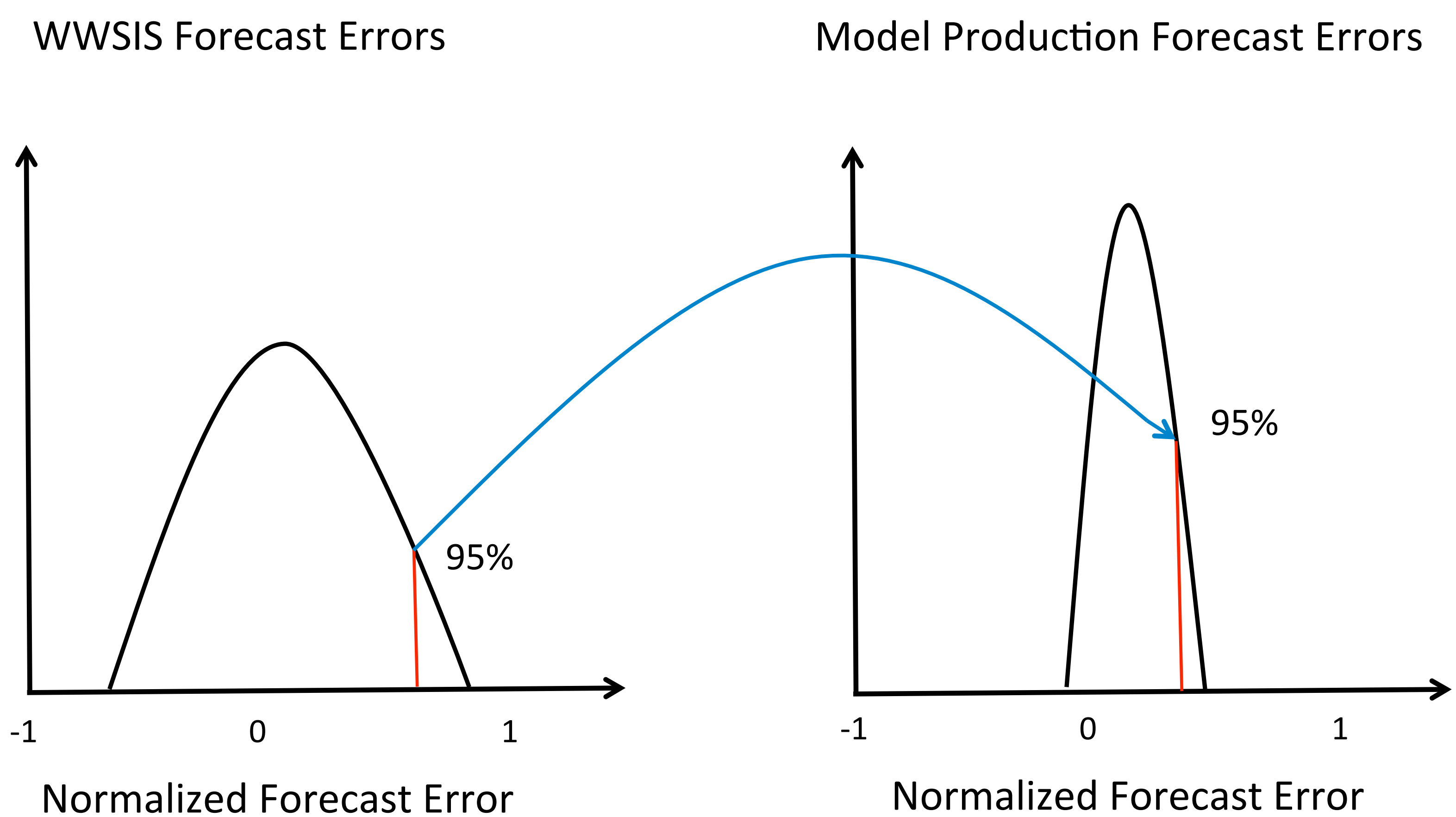
Revised wind data

- Fixed 3-day seam from WWSIS-1 data
- Statistical down-sampled 10 min to 1 min wind outputs
- Adjusted day-ahead forecasts to match distributions of measured forecasts
- Created 4-hour-ahead forecasts using 2 hour persistence





Mapping Forecast Errors



Refine shapes of WWSIS forecast error distributions to match shapes of CAISO/ERCOT/XCEL forecast errors

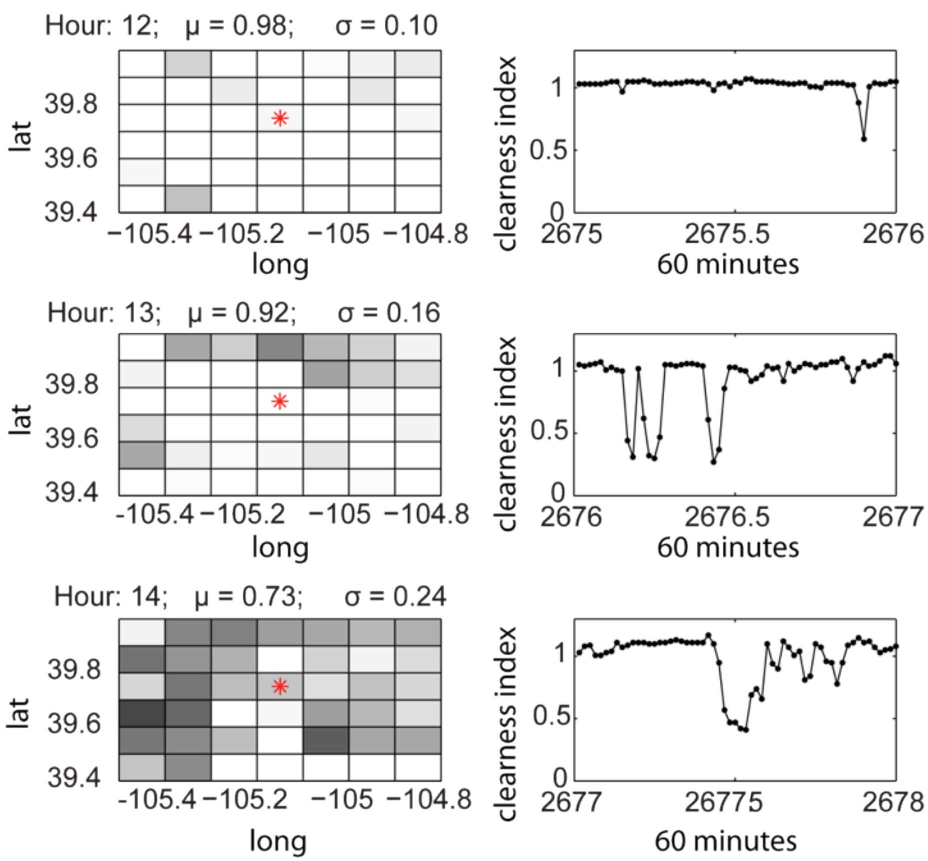
Solar Data

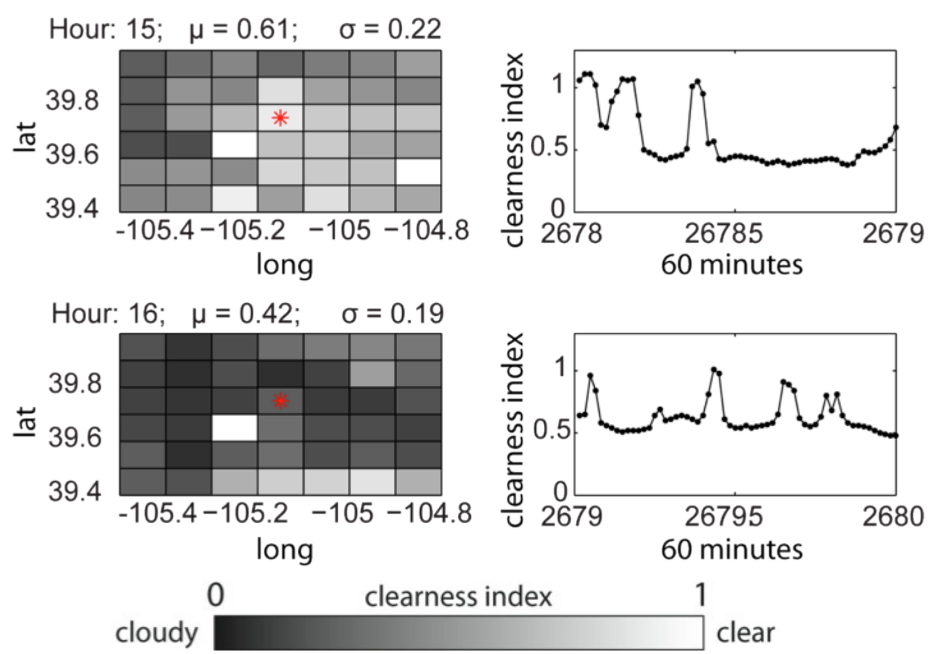
Revised solar data

- New methodology to synthesize 1 min rooftop PV, utility-scale PV, and CSP output
- Solar day-ahead forecasts were unchanged
- 4-hour-ahead forecasts were synthesized using 2-hour persistence of cloudiness
- 1-hour-ahead forecasts were synthsized using 1-hour persistence of cloudiness

Site Clearness Index Analysis

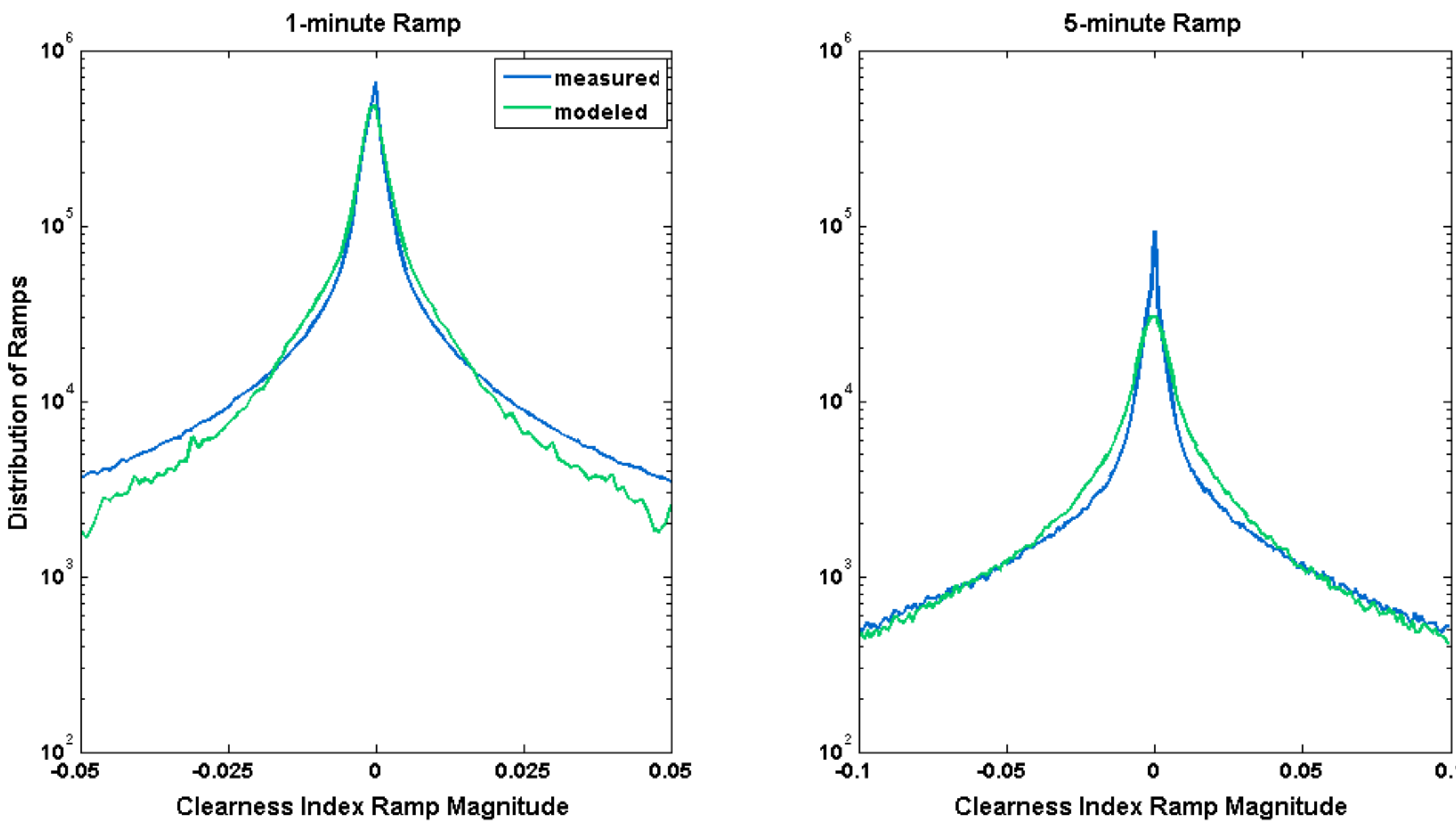
Spatial satellite data is used to calculate the relative proportions of cloud cover in an area for each hour. This data is related to the sub-hourly measurements of irradiance. These figures show five consecutive hours of aerial satellite data (left) and corresponding minutely ground-based irradiance data (right).





Satellite data is from Clean Power Research's SolarAnywhere

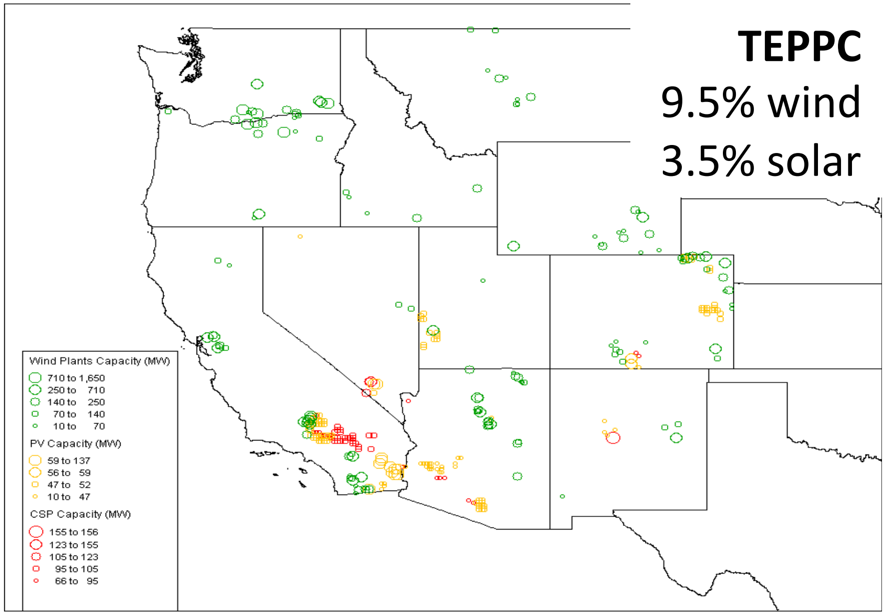
Ramps (Synthetic and Measured)



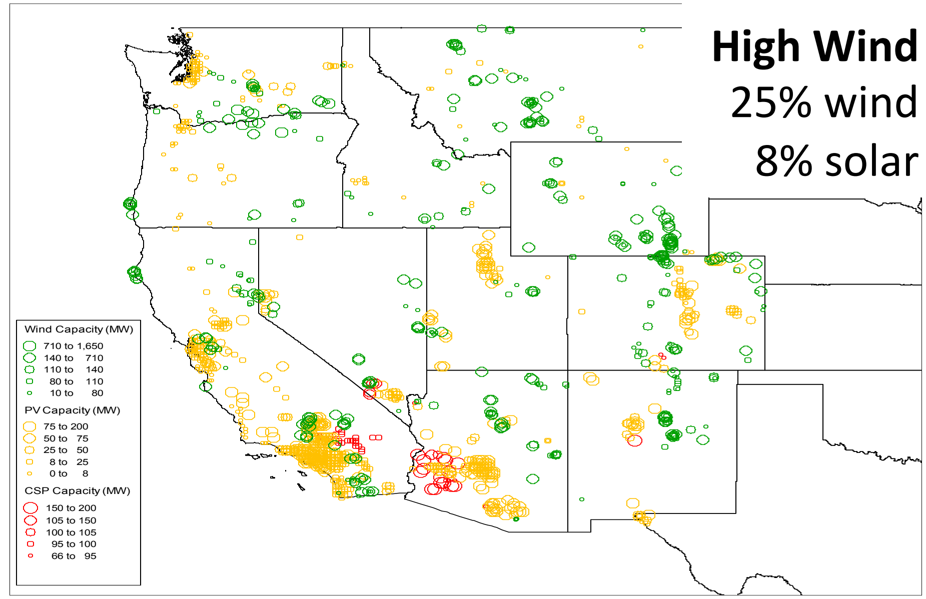
Scenarios

Siting with REEDS model

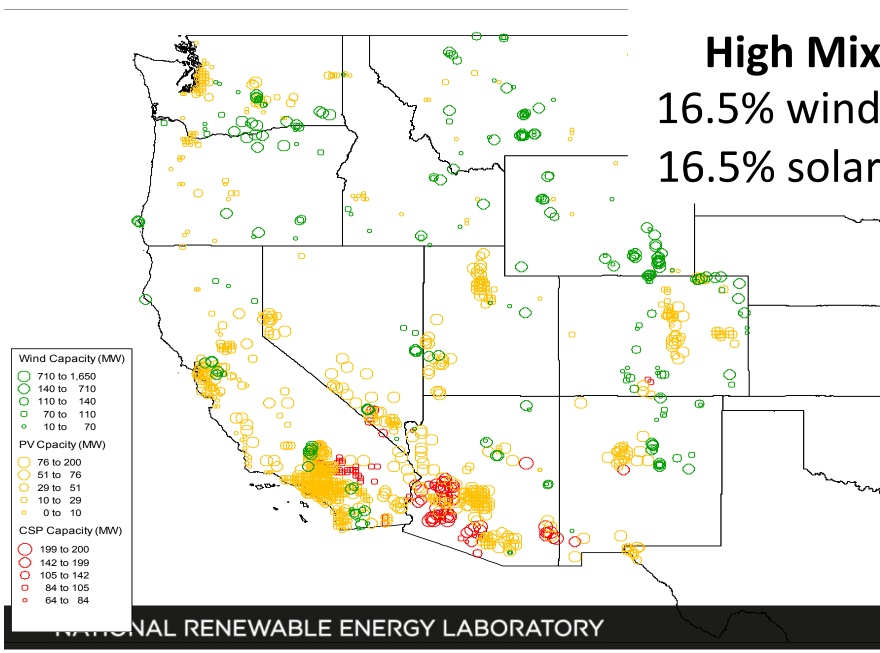
TEPPC
9.5% wind
3.5% solar



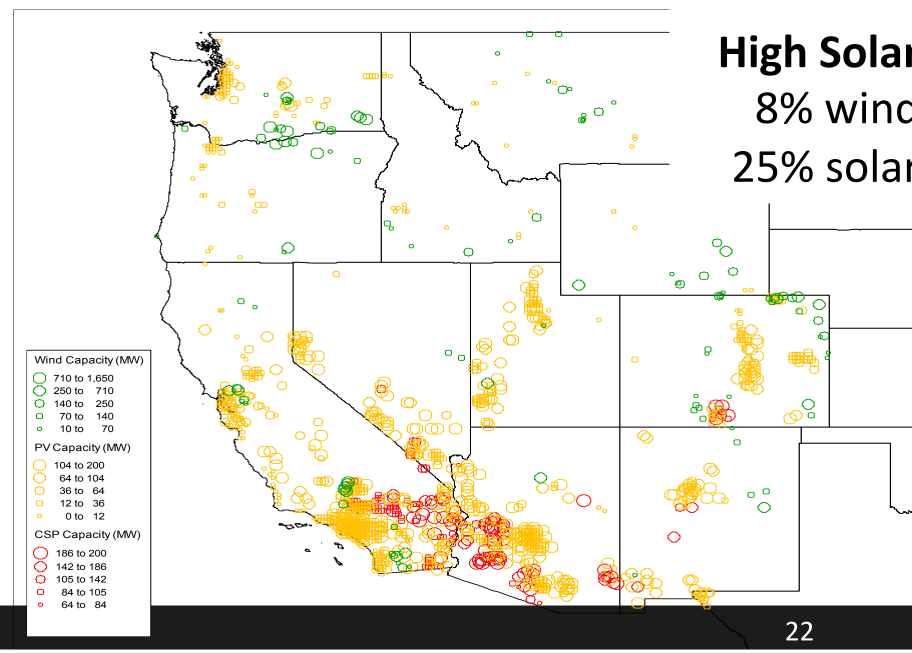
High Wind
25% wind
8% solar



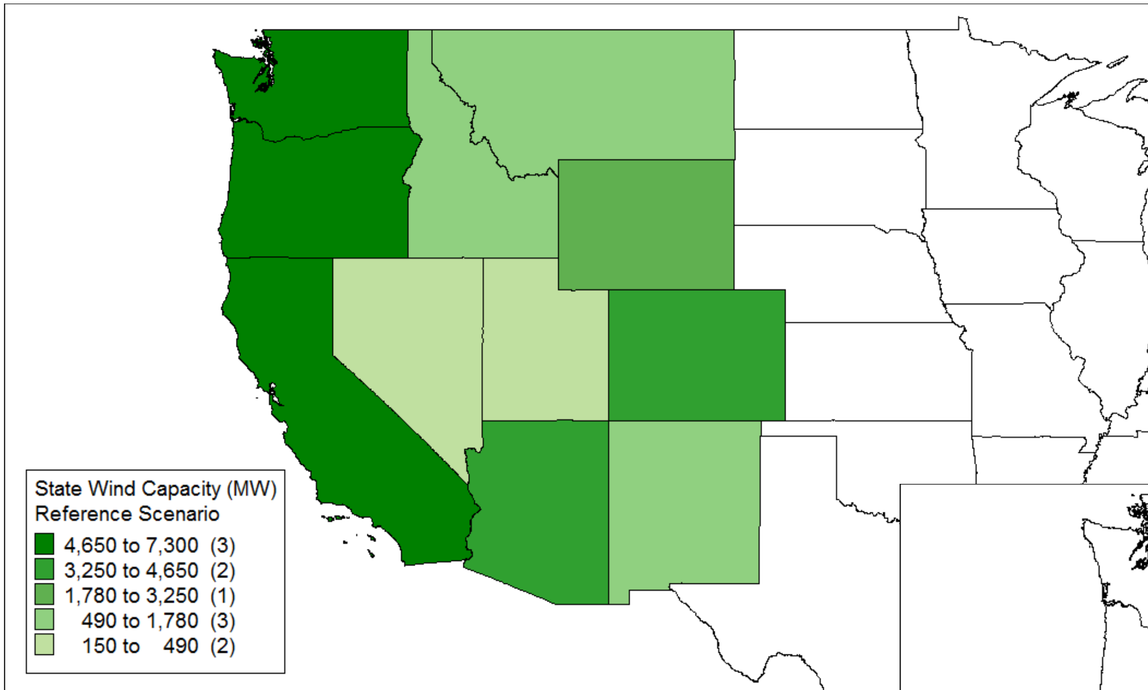
High Mix
16.5% wind
16.5% solar

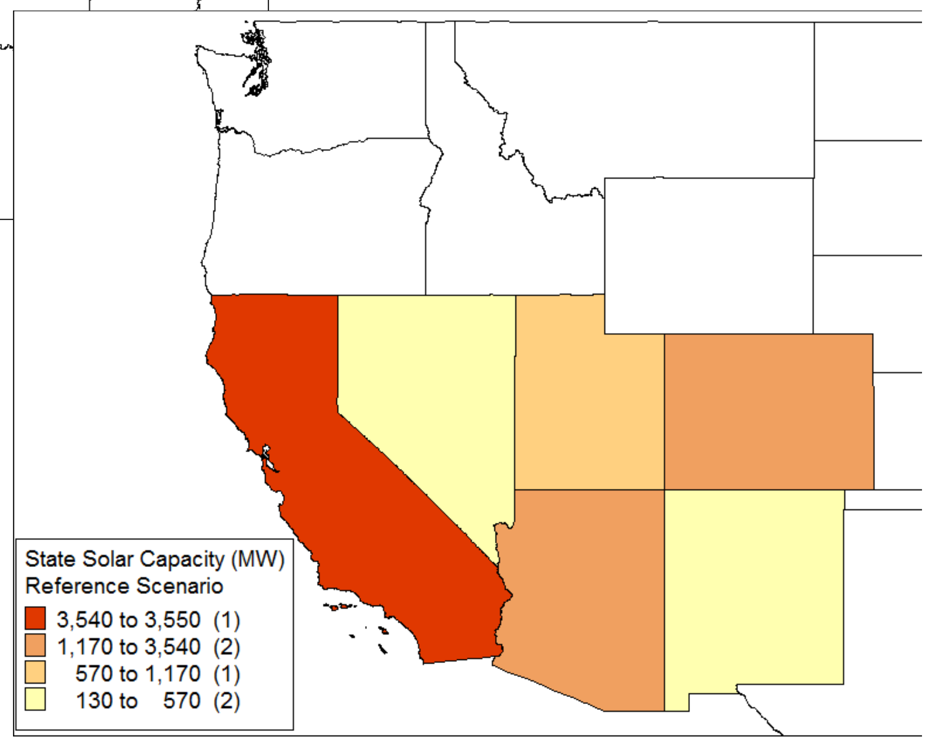


High Solar
8% wind
25% solar



TEPPC Scenario





TEPPC
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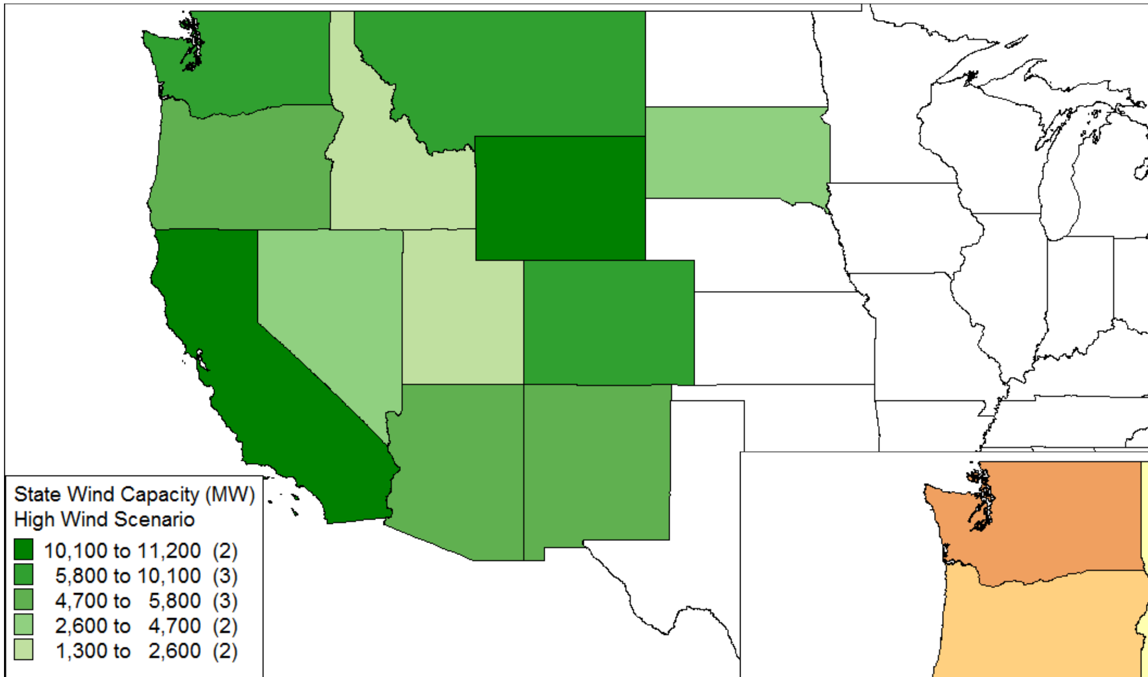
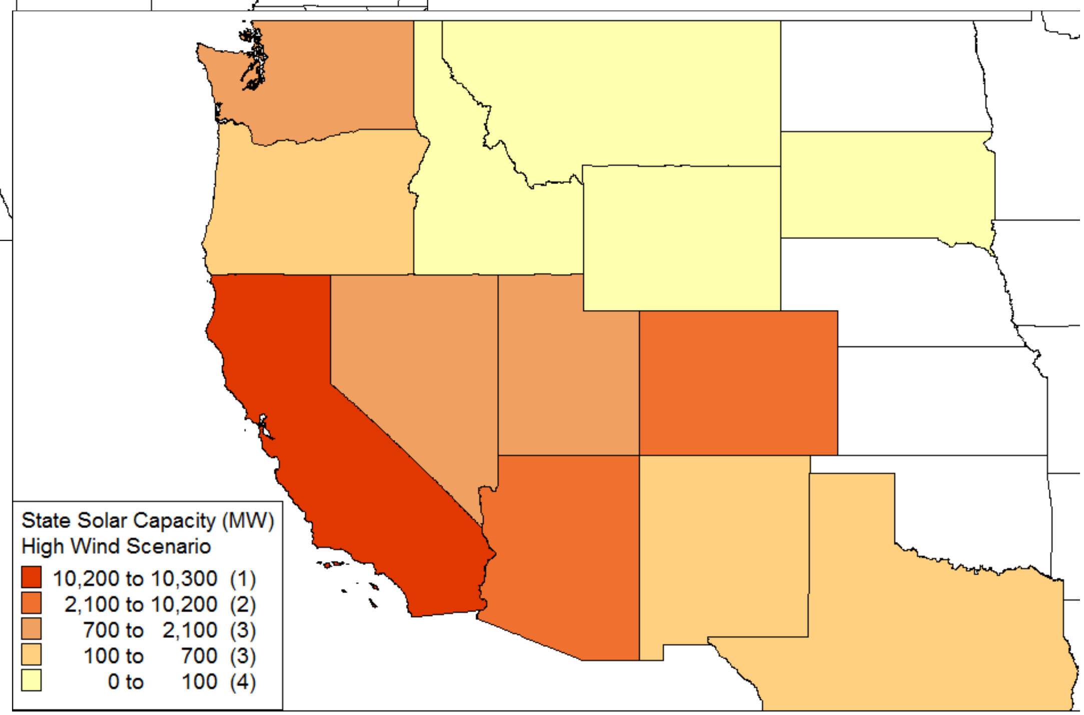
3.5% solar

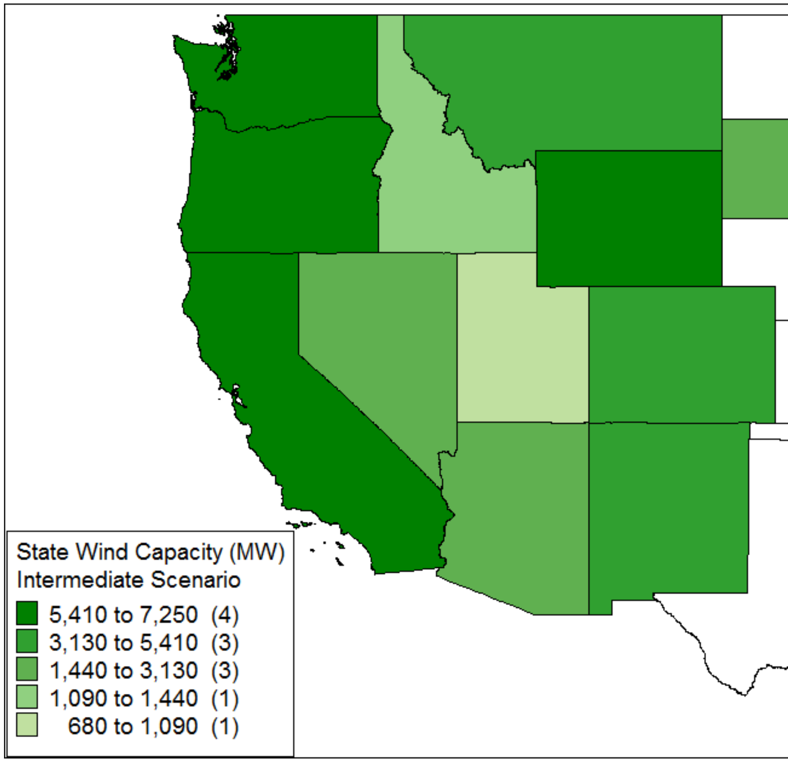
High Wind Scenario

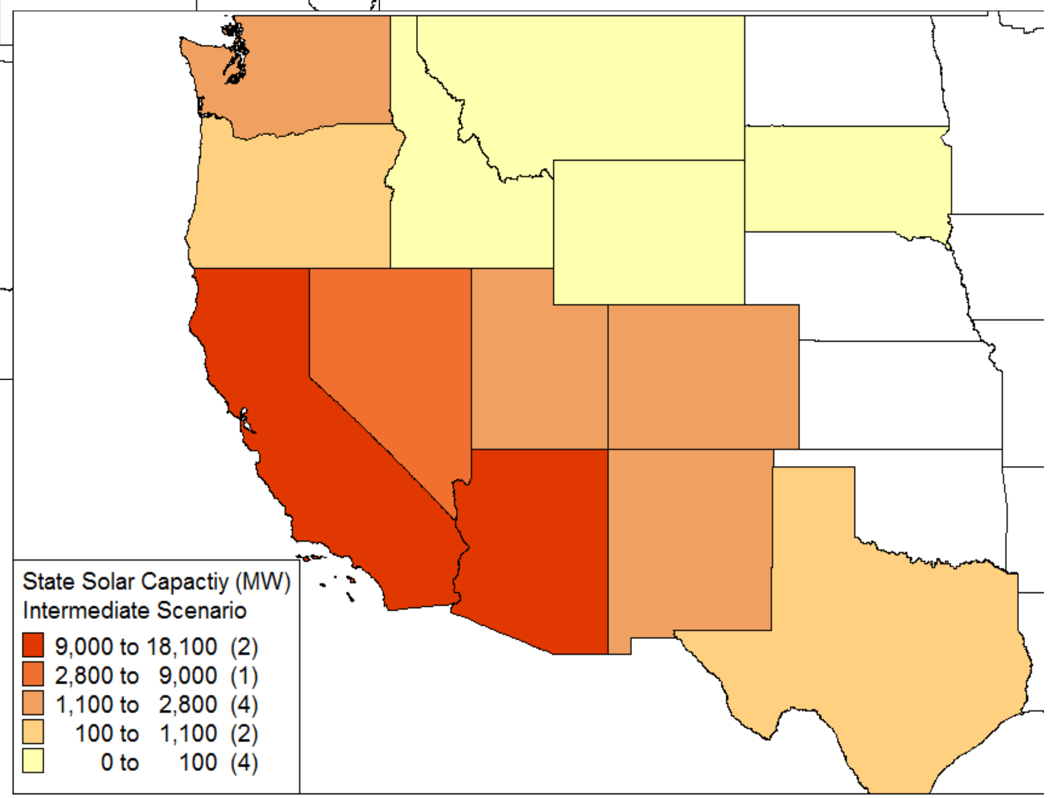




High Wind
25% wind
8% solar

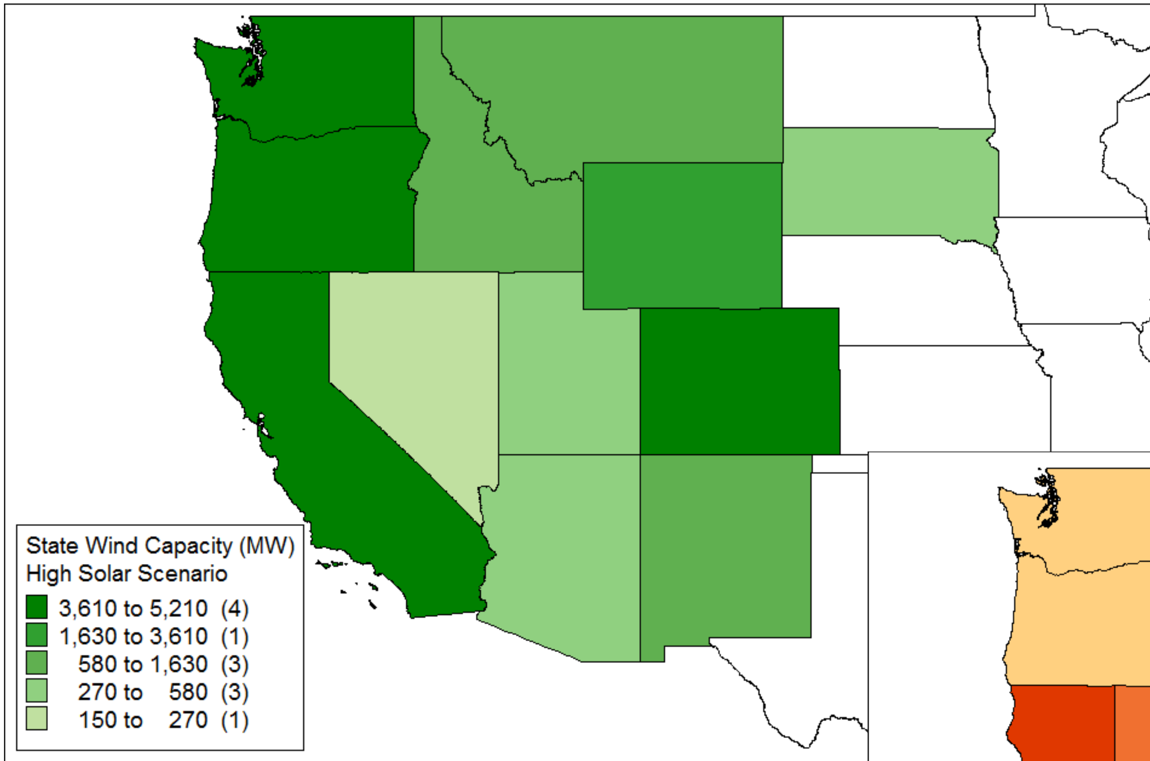
High Mix Scenario





High Mix
16.5% wind
16.5% solar

High Solar Scenario



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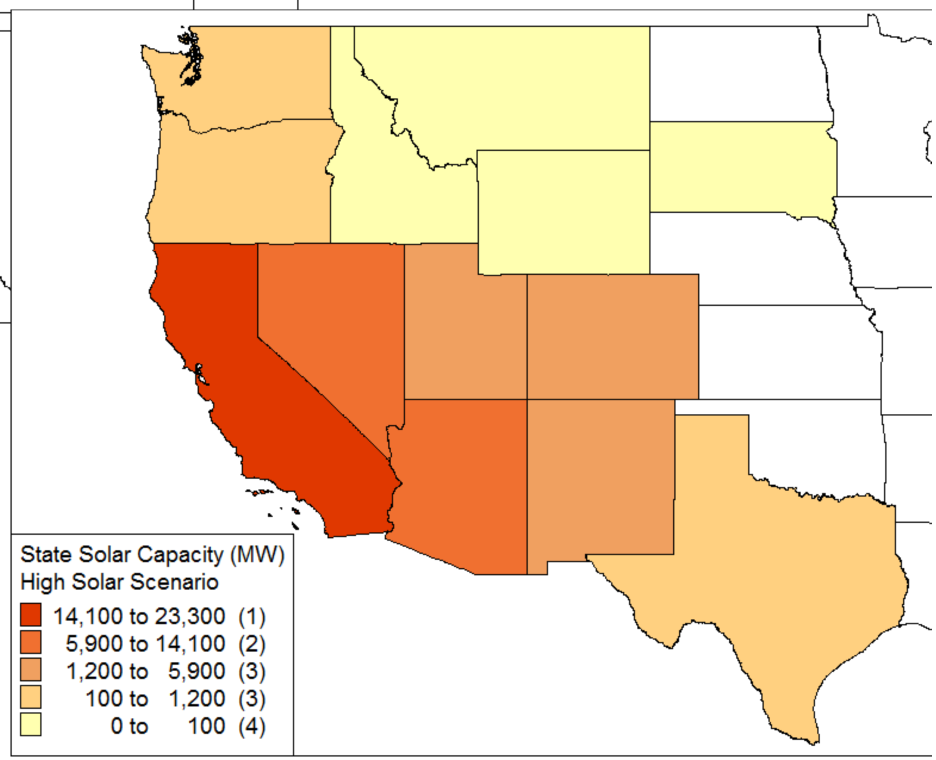

Scenarios

	PV (MW)	CSP (MW)	Wind (MW)	Total (MW)
TEPPC (9.5% wind, 3.5% solar)	7037	4352	27,903	39,328
High Wind (25% wind, 8% solar)	20,063	6536	63,843	90,442
High Mix (16.5% wind, 16.5% solar)	40,374	13,997	43,120	97,491
High Solar (8% wind, 25% solar)	61,940	21,527	23,359	106,826

- All wind and solar is sited in US portion of Western Interconnection. 2020 peak WECC load is 171 GW, of which 147 GW is in the US. TEPPC case uses same MW as TEPPC but all sited in US, giving 13% total VG penetration
- CSP has 6 hours storage
- WECC TEPPC 2020 PC1 case

For more details

- Results www.nrel.gov/docs/fy12osti/56171.pdf www.nrel.gov/docs/fy12osti/56217.pdf
- Emissions and wear and tear summary www.nrel.gov/docs/fy12osti/53504.pdf
- Wear and tear costs and impacts www.nrel.gov/docs/fy12osti/55433.pdf
- Cycling Cost Analysis www.nrel.gov/docs/fy12osti/54864.pdf
- Forecasts www.nrel.gov/docs/fy12osti/54384.pdf
- Reserves www.nrel.gov/docs/fy12osti/56169.pdf
- Solar validation energy.sandia.gov/wp/wp-content/gallery/uploads/2012_Hansen_WWSIS_irradiance_sim_validation_final.pdf